

Contemporary Sediment Transport Processes Through Submarine Canyon Heads

P. Puig

Institut de Ciències del Mar (CSIC)
Passeig Marítim de la Barceloneta, 37-49
Barcelona 08003, Spain

phone: +34 93 230 9518 fax: +34 93 230 9555 email: ppuig@icm.csic.es

Grant Number: N00014-04-1-0379

<http://www.icm.csic.es>

LONG-TERM GOAL

The long-term goal of this research effort is to understand the oceanic processes that transport, erode and deposit sediment within submarine canyon heads, and contribute to the sediment transfer from the shelf to the continental slope.

OBJECTIVES

Several specific objectives are being pursued

- (1) identify the principal off-shelf sediment transport mechanisms acting within northwestern Mediterranean submarine canyon heads, including short-term (i.e. hours to weeks) and long-term (e.g. seasonal) processes,
- (2) evaluate the relative importance of different processes in the down-canyon sediment transfer (gravity-driven versus current-driven),
- (3) study the role of intermediate nepheloid layer detachments as actual transfer pathways of suspended sediment particles from the continental shelf to canyons and
- (4) provide sediment dynamic constraints for the interpretation of the sedimentary record within submarine canyons.

APPROACH

The proposed technical approach included the deployment (in the axis of the canyon head) of a bottom boundary layer (BBL) tripod at 145-m depth, together with the deployment of three moorings, at 200-, 500- and 750-m depth. The tripod was equipped with a downward-looking pulse coherent acoustic doppler profiler (PCADP), six optical back-scatter sensors (OBS), an acoustic back-scatter sensor (ABS), an upward-looking acoustic doppler current profiler (ADCP) and an Aanderaa RCM9 current-meter; the 200-m mooring was equipped with an RCM9 current-meter located 5 meters above the bottom (mab) and a string of temperature and turbidity sensors; the 500-m mooring was equipped with an RCM9 current-meter at 5 mab and a 12-cup sequential sediment trap located at 30 mab; and the 750-m mooring was equipped with an RCM9 current-meter at 5 mab. This observational effort had a duration of 7 months to capture seasonally varying processes, and a mid-deployment cruise was

Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE 30 SEP 2005		2. REPORT TYPE		3. DATES COVERED 00-00-2005 to 00-00-2005	
4. TITLE AND SUBTITLE Contemporary Sediment Transport Processes Through Submarine Canyon Heads				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Institut de Ciències del Mar (CSIC), Passeig Marítim de la Barceloneta, 37-49, Barcelona 08003, Spain, ,				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES code 1 only					
14. ABSTRACT The long-term goal of this research effort is to understand the oceanic processes that transport, erode and deposit sediment within submarine canyon heads, and contribute to the sediment transfer from the shelf to the continental slope.					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 6	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

conducted for instrumentation refurbishing. During cruises, water column measurements were conducted with a CTD+transmissometer to evaluate the distribution of nepheloid structures within the canyon. This instrument was able to reach the seabed and it was equipped with a bottom trigger mechanism to collect water samples in the BBL.

The tripod provided suspended sediment concentration (SSC) measurements (OBS & ABS) and velocities (PCADP) at numerous heights (< 1 m) above the seabed to investigate the occurrence of down-canyon sediment-gravity flows. The upward-looking ADCP collected velocity profiles through the entire water column to determine the influence of the canyon topography on the current direction, particularly above the canyon rims. The RCM9 current-meters placed on the tripod and on the moorings generated time-series at high frequencies (i.e. 20 minutes) and provided information on short-term variability in water properties, SSC and sediment fluxes. The string of temperature+turbidity sensors installed on the mooring was used to assess the presence of internal wave activity and identify nepheloid layer detachments, while the sediment trap collected near-bottom was used to characterize the settling particle fluxes. Additionally, the information derived from the water column profiling provided relationships between the hydrographic structure and the development of nepheloid layers.

WORK COMPLETED

During FY05 the entire field data set was collected by the moored instruments described in the approach section. The ICM group participated in three oceanographic cruises on board the RV Oceanus in September 04, and on board the RV Endeavor in February and April 05 (instruments deployment, refurbish and recovery). During these cruises water column measurements were conducted in collaboration with G.C. Kineke (Boston College) and X. Durrieu de Madron (Univ. of Perpignan).

Regarding meeting attendance, in June 03 we presented the preliminary results of this study at the ASLO Summer Meeting, held in Santiago de Compostela, Spain.

RESULTS

During the preceding winter, in the frame of the EU EuroStrataform Project, seven submarine canyon heads along the Gulf of Lions were monitored with instrumented moorings deployed at 300 m water depth (Palanques et al., 2005). The objective of these deployments was to investigate the processes by which sediment is transferred from the continental shelf to a suite of submarine canyons incised in a river-dominated margin. Results obtained during these previous deployments demonstrated that the Gulf of Lions submarine canyons are active conduits of sediment during present conditions, and that the major mechanism contributing to the sediment transport are eastern storms and shelf water cascading.

In the Gulf of Lions winter heat losses and evaporation caused by cold and dry northerly winds (Tramontane and Mistral) induce cooling and mixing of the coastal waters, which eventually become denser than the surrounding waters and sink (Bethoux et al., 2002; Durrieu de Madron et al., 2005). After traveling on the shelf, they flow down the continental slope –preferentially through submarine canyons– until they reach their equilibrium (neutral density contrast) level. Such a process is known as shelf or dense water cascading.

Shelf water cascading events during winter 2003-04 were characterized by decreases in temperature and increases in current speed and occurred frequently from January to May in the W sector of the Gulf of Lions –where they were more intense–, and from February to April in the E sector. These events lasted few days and often begun and/or were enhanced during eastern storms, which caused increases in suspended sediment concentration, and contributed to amplify the sediment fluxes. The preferential direction of the coastal currents, the width of the shelf and the coastal topographic constrain causes that most of the sediment transport occur through the Cap de Creus Canyon (the westernmost one), where observed sediment fluxes were two orders of magnitude higher than in the eastern and central submarine canyons (Palanques et al., 2005). Based on these previous results, the Cap de Creus Canyon was selected among all the Gulf of Lions submarine canyons as the study site to conduct this new research effort.

Temporal series of near-bottom temperature, current speed and SSC measured by the RCM9 current meters installed in each instrumented site along the Cap de Creus Canyon axis summarize the major findings of this study (Fig. 1). During winter 2004-05, the persistent northerly winds and the absence of river discharges that contribute to increase buoyancy of coastal waters helped to dramatically enhance the intensity of the shelf water cascading mechanism. Under this weather conditions, cascading in the Cap de Creus Canyon begun in early November (much earlier than in the preceding year) and took place without being triggered by eastern storms. During the first events, this process only affected the canyon head, causing significant increases in SSC, but in late December-early January a major cascading event reached greater depths and moved the 200-m and 500-m moorings down-canyon at several steps until they stopped at approximately 600-m water depth (the records after this displacement are illustrated in grey color in Figure 1). The following cascading event reached down to 750-m depth and caused a large peak in SSC which was observed earlier in the deeper parts of the canyon than in the canyon head. From late January to early March cascading occurred continuously, although showing periodic fluctuations that lasted between 3-6 days and were particularly well defined at 750-m depth. These fluctuations coincided with changes in the current direction, being the highest velocities directed to WNW (i.e. coming from the southern wall). Temperature and SSC also fluctuated with the same periodicity, but towards the final stages of cascading the magnitude of the SSC peaks decreased dramatically. These observations confirm that cold dense water cascading in the Gulf of Lions is an effective off-shelf transport mechanism through the Cap de Creus Canyon, and suggest that once the cascading process is well established it occurs preferably through the southern canyon wall. In this situation, the associated high currents winnow the fine sediments deposited in the canyon floor (preferably from the canyon axis and southern wall), being transported down-canyon to depths below 750 m.

Although from the available observations shelf water cascading seems to occur in the Gulf of Lions canyon heads in a yearly basis, the magnitude of this transport mechanism during winter 2004-05 suggest that it corresponded to an exceptional year that probably affected the entire submarine canyon, transporting sediment down the North-Balearic basin.

IMPACT/APPLICATION

This effort will help to improve the knowledge about the mechanisms responsible for the off-shelf transport of sediment through submarine canyon heads, providing information for the interpretation of the sedimentary record within submarine canyons. The observed processes will be very useful for development and improvement of sediment transport and accumulation models, preferentially in places where dense water formation in shelf environments is likely to occur. The identification and

characterization of such gravity flows in submarine canyons heads will also provide insights for slope stability and submarine canyons formation studies.

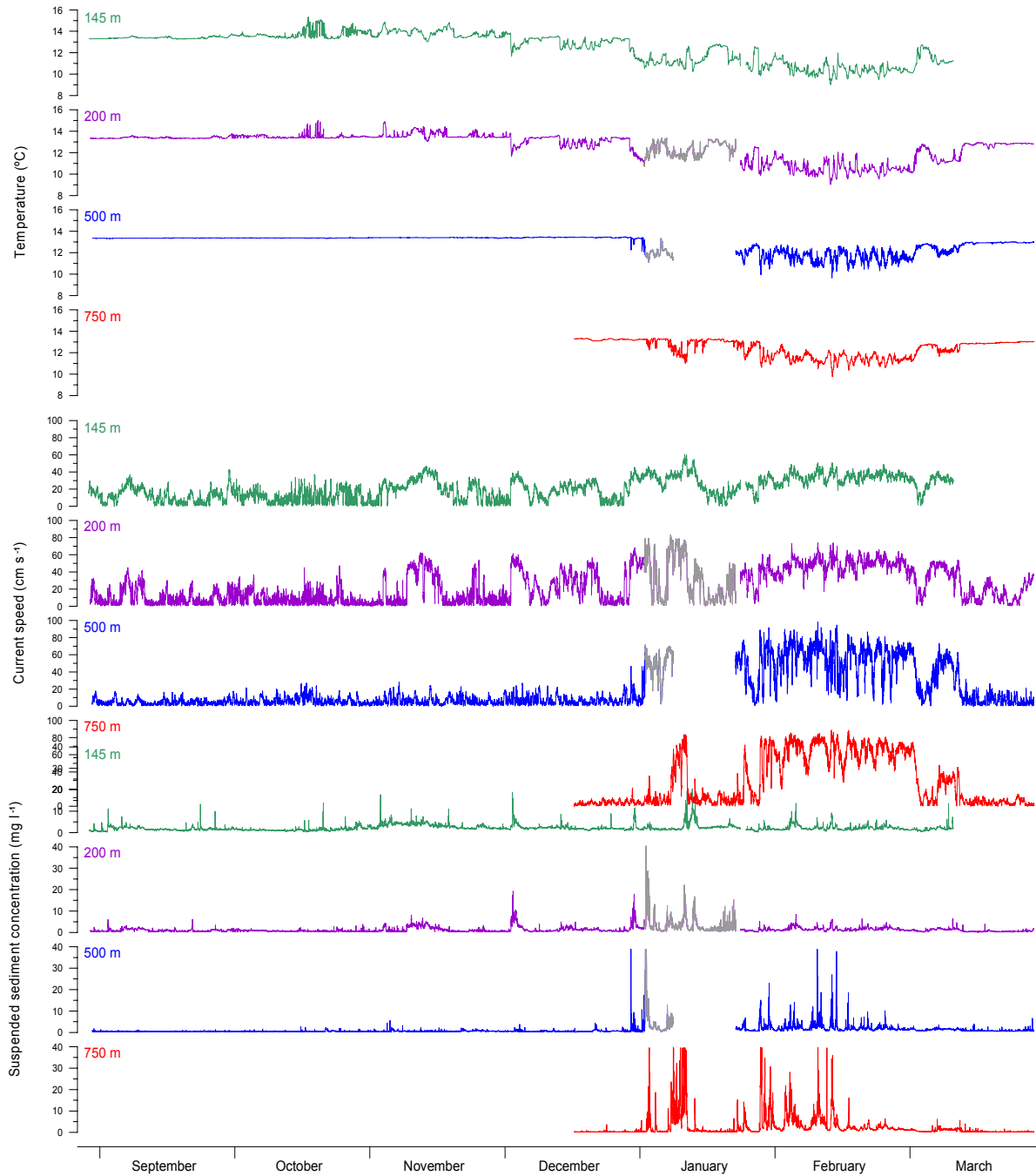


Figure 1. Time series of near-bottom temperature, current speed and SSC measured by the RCM9 current meters installed at several depths along the Cap de Creus Canyon during winter 2004-05.

Note the occurrence of several shelf water cascading events in the shallower sites and the long-lasting episode from late January to early March when cascading was well established and affected the entire canyon head. Grey lines correspond to periods during which the 200- and 500-m moorings moved down-canyon

RELATED PROJECTS

EU EuroStrataform (EVK3-CT-2002-00079 Project, EU Fifth Framework Program: Energy, Environment and Sustainable Development). In addition, this observational effort will be a joint collaboration with other ONR funded researchers, A. Ogston (UW), G.C. Kineke (Boston College),

B.L. Mullenbach (TAMU), C. Nittrouer (UW), C. Sherwood (USGS), as well as with personnel at the University of Perpignan (CEFREM), X. Durrieu de Madron and S. Heussner.

REFERENCES

Bethoux, J.P., Durrieu de Madron, X., Nyffeler, F., Tailliez, D. (2002). Deep water in the western Mediterranean: peculiar 1999 and 2000 characteristics, shelf formation hypothesis, variability since 1970 and geochemical inferences. *Journal of Marine Systems*, 33-34: 117-131.

Durrieu de Madron, X., Zervakis, V., Theocharis, A., Georgopoulos, D. (2005) Comments on “Cascades of dense water around the world ocean”. *Progress in Oceanography*, 64: 83-90.

Palanques, A., Durrieu de Madron, X., Puig, P., Fabr s, J., Guill n, J., Calafat, A., Heussner, S., Canals, M., Bonin, J. (2005). Suspended sediment fluxes and transport processes in the Gulf of Lions submarine canyons. The role of storms and dense water cascading. *Marine Geology*, submitted.

PUBLICATIONS

Puig, P., Palanques, A., Guill n, J. Sediment transport processes through the Cap de Creus submarine canyon. ASLO Summer Meeting 2005, Santiago de Compostela, Spain.